PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : F03B 13/22, 7/00

A1

(11) International Publication Number: WO 99/20896

(43) International Publication Date: 29 April 1999 (29.04.99)

(21) International Application Number: PCT/SE98/01640

(22) International Filing Date: 15 September 1998 (15.09.98)

(30) Priority Data:
9703852-5 22 October 1997 (22.10.97) SE

(71)(72) Applicant and Inventor: LAGSTRÖM, Göran [SE/SE]; Essingeringen 72C, S-112 64 Stockholm (SE).

(74) Agent: WINBLAD, Peter; Albihns Patentbyrå Stockholm AB, P.O. Box 3137, S-113 67 Stockholm (SE).

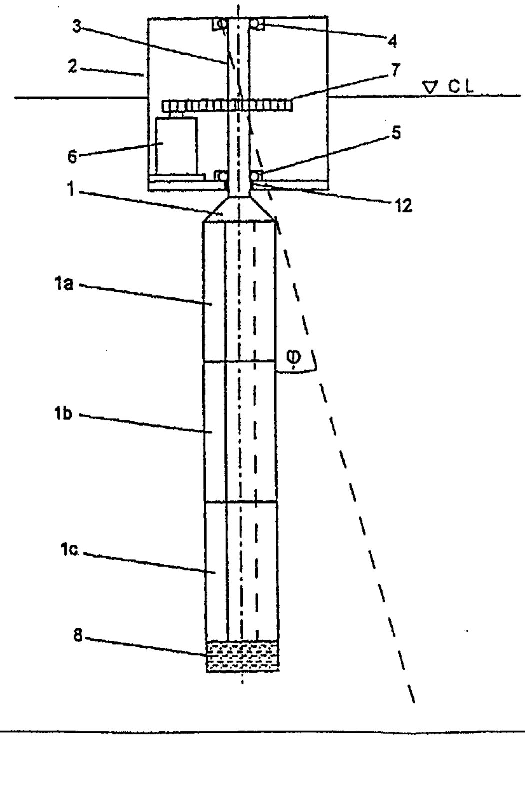
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, HR, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: METHOD AND ARRANGEMENT FOR CONVERTING KINETIC ENERGY OF OCEAN CURRENTS INTO ROTATORY ENERGY

(57) Abstract

A method and arrangement for converting kinetic energy of ocean currents into rotatory energy, using at least one turbine (1) of so-called Savonius type which is arranged to extend substantially vertically from a buoy (2) anchored in such a way in an ocean current that it cannot rotate with the turbine and driving an electric generator (6) or another rotary machine. At the bottom of the turbine (1) a counterweight (8) is provided to retain the turbine (1) substantially vertically at normal speed of the ocean current but to permit it to assume an inclined position when subjected to temporarily increased current speeds, thereby protecting the turbine from harmful flexural stresses and protecting the rotary machine (6) from being overloaded.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

Method and arrangement for converting kinetic energy of ocean currents into rotatory energy

The present invention relates to a method of converting the kinetic energy of ocean currents into rotatory energy with the help of a so-called Savonius type turbine, and to use this energy for driving a rotary machine, such as primarily an electric generator.

The Savonius turbine has earlier only been used in small wind turbines having electric generators of up to 1kW, the reason being that at high wind speeds it is subjected to high flexural stresses, for which a large turbine cannot be dimensioned if it is to be capable of producing electric energy at a competitive price per kWh at average wind speeds.

In Sweden, the average wind speed is approx. 6 m/s, but during extreme conditions it can amount to more than 45 m/s.

The Savonius turbine cannot be protected against high wind speeds by means of feathering, as is the case in air screw turbines, and it has only approx. 50% of the efficiency of such a turbine. It is advantageous, however, in that it is cheap to manufacture, rotates in the same direction regardless of the direction of the wind and will start already at less than 1 m/s, as compared to 3-4 m/s for an air screw turbine.

If the Savonius turbine is provided with an electric generator, an electric power is produced amounting to

$$Pel = 0{,}12 \times S \times B \times H \times v^3,$$

S being the density of air = 1,3 kg/cu.m., H the height of the turbine in m, B its width in m and v the wind speed in m/s.

The flexural stress is proportional to the square of the wind speed and will be, for the above-mentioned speeds, $45^2 : 6^2 = 56{,}25$ times larger at 45 m/s than at 6 m/s.

In ocean currents, the conditions are totally different and more advantageous, as the variations in speed are much smaller. Even for tidal flows, the speed variations are very far from being as large as in the case of wind speeds. Therefore, a Savonius type turbine can, to an advantage, be used as a hydraulic turbine in ocean currents to convert their kinetic energy into rotatory energy.

It is thus possible, in ocean currents, to produce environmentally compatible energy at a very competitive price in comparison with other types of energy. The density of water being S = 1000 kg/cu.m., Pel = 0,12 x 1000 x B x H x v^3 Watt.

The way of using a Savonius turbine in accordance with the present invention also makes it possible to obtain a kind of feathering effect on the turbine, so that neither the turbine, nor its electric generator runs a risk of being overloaded.

This advantageous way of using a Savonius turbine in ocean currents and of protecting the turbine and the electric generator from being overloaded has been achieved with the method in accordance with the present invention as it is defined in Claim 1.

The present invention also relates to an arrangement for carrying out the inventive method. The main features of the arrangement are defined in the independent claim 7.

The invention is described in the following with reference to Figs. 1-7.

Fig. 1 is a schematic side view, partly in section, of a power plant in accordance with the invention.

Fig. 2 is a schematic end view showing the turbine of the plant.

Fig. 3 shows, schematically, from above, an arrangement of 10 power plant units with electric cables leading to a central unit.

Fig. 4 shows, schematically, from above, a power plant unit and its anchoring arrangement.

Figs. 5-7 show, schematically, from above, different arrangements of a number of turbines suspended from a common buoy or pontoon.

A Savonius type turbine 1 (Fig. 1) is journalled watertight with the help of seal rings or the like 12 in a floating buoy 2 with the help of a shaft 3, a ball bearing 5 and a conical bearing 4.

The turbine 1 is preferably made with three rotor units 1a -1c, one below the other and displaced 120° in relation to each other in order not to cause a turning moment which varies too much, corresponding to the relationship in a 3-phase electric motor relative to a single-phase motor.

The rotor units 1a -1c with partition walls are preferably made of high-grade sheet steel painted with a thick coat of a multi-component paint which also protects against on-growth of marine organisms.

In the buoy 2, an electric generator 6, such as a three-phase alternating current generator, is provided which is preferably driven via some type of step-up transmission, for example a gear mechanism 7. The turbine 1 is fitted with a counterweight 8 at its bottom, which together with the turbine's own weight is so dimensioned that when the speed of the ocean current temporarily exceeds the normal speed, the turbine will not be suspended substantially vertically from the buoy but will take up a more oblique position, the angle of which increases in relation to the increase of the speed of the current. A reduced area of the turbine blades is hereby exposed to the water current, and the water will act on the turbine at an oblique, less efficient angle than the normal one. This reduces the flexural

stresses as well as the loading of the generator and will have an effect corresponding to that of feathering.

If the turbine is swung out to φ degrees, for example, the effect of the generator will be proportional to $\cos^3\varphi$ and the flexural stress proportional to $\cos^2\varphi$. In this way, a reliable, simple, robust and fully automatic overload protection is obtained.

The counterweight 8 can be made, for example, as a sand-filled box or a lump of concrete.

The rotatory energy produced by the turbine can also be used for other applications, for example to drive a pump in order to pump water over sorbents which extract valuable ions from the sea water.

In the following example, the produced electric effect Pel is calculated for a Savonius turbine with the height H = 12 m and the width B = 4 m in a 5-knot ocean current.

5 knots correspond to 5 nautical miles/h = 5 x 1852 : 3600 = 2,572 m/s.
Pel = 0,12 x 1000 x 12 x 4 x $2{,}572^3$ = 98000 W = 98 kW.
At 7 knots, Pel = $7^3 : 5^3$ x 98 kW = 250 kW.

Current speeds equal to those stated above and even higher are found in large ocean areas on our planet. Tidal flow speeds of up to 15 knots can be found in narrow straits and at river mouths, which makes it possible to produce electric energy at an especially low price per kWh.

Ocean currents often pass close to shores and can therefore be utilized without any requirement for long and, thereby, expensive electric cables on the bottom of the sea for taking the electric current ashore.

The electric current produced will usually show variations in frequency. With the help of known power electronics and a transformer, however, these can be eliminated and a suitable frequency and voltage obtained in order to avoid too great landing losses, whereupon the current can again, on shore, be transformed into a voltage suitable for new or existing supply networks.

A large power plant can be built consisting of, for example, ten separate buoy power stations designated B (see Fig. 3), each having a capacity in accordance with the example given above. In such a case, each buoy station B is connected by electric cables 9 to a common central buoy station 10 provided with suitable equipment, such as circuit breakers and disconnectors, transformer and protective relays, in a way known per se. From this central buoy, a common cable 11 running along the bottom of the sea connects with land.

The ten buoy power stations are arranged in a straight line or in some other optimized configuration, depending on the normal variations of the direction of the ocean current, so that they do not "steal" kinetic energy from each other. The individual buoys are anchored, preferably with the help of three anchor chains 13 with anchors 14 (Fig. 4) displaced 120° in relation to each other, so that the buoys cannot rotate with the turbine. The central buoy station 10 is also anchored in a similar way, not shown.

If the ocean current varies little in direction, or with 180° displacement - which is often the case with tidal flows - it can be suitable to place the turbines in a common buoy or pontoon 15, as shown from Figs. 5 -7 which show examples of possible configurations.

The buoys or pontoons should be fitted with a top-light and proper lighting in accordance with prevailing regulations.

Claims

1. A method of converting kinetic energy of ocean currents into rotatory energy, **characterized** in that at least one turbine (1) of so-called Savonius type is arranged to extend downwards and substantially vertically from a buoy (2) anchored in such a way in an ocean current that it cannot rotate with said turbine (1), a shaft (3) of said turbine being rotatably journalled in said buoy (2) and arranged to drive, preferably with the help of a transmission device (7), a rotary machine, such as an electric generator (6), and that, at the bottom end of said turbine (1), a counterweight (8) is fitted which, together with said turbine's (1) own weight, is dimensioned to retain said turbine (1) in said substantially vertical position at normal speed of the ocean current but to permit said turbine (1) to assume a suitable angle of inclination (φ) when subjected to temporarily increased current speeds, thereby protecting said turbine (1) from harmful flexural stresses and protecting said rotary machine (6) from being overloaded.

2. A method in accordance with Claim 1, **characterized** in that said turbine (1) is fitted with a plurality of rotor units (1a -1c) arranged one below the other on said shaft (3) and displaced evenly in relation to each other around the circumference of said shaft (3), preferably three rotor units displaced 120° in relation to each other.

3. A method in accordance with any of Claims 1-2, **characterized** in that, with the help of power electronics, the electric current produced when said turbine (1) is used to drive an electric generator (6), is converted into a suitable frequency and voltage.

4. A method in accordance with any of Claims 1-3, **characterized** in that a plurality of power producing units (B) comprising said buoys (2) with turbines (1) are anchored to form a group and to feed, by cables (9), the electric current produced to a collecting buoy (10) and from there, preferably with the help of one single cable (11), to the shore.

5. A method in accordance with Claim 4, **characterized** in that said power producing units (B) comprising said buoys (2) with turbines (1) are anchored in such a way that none of them obstructs the flow of the ocean current's kinetic energy to another unit.

6. A method in accordance with any of Claims 1-3, **characterized** in that, in the case that the ocean current varies little in direction, or always varies mainly by 180°, a desired number of said turbines (1) with electric generators (6) and other equipment required are arranged, in a suitable configuration, in a common, large buoy or pontoon (15).

7. An arrangement for converting kinetic energy of ocean currents into rotatory energy, **characterized** in that at least one turbine (1) of so-called Savonius type is arranged to extend downwards and substantially vertically from a buoy (2) adapted to be non-rotatably anchored in an ocean current, a shaft (3) of said turbine being rotatably journalled in said buoy (2) and arranged to drive, preferably with the help of a transmission device (7), a rotary machine, such as an electric generator (6), and that, at the bottom end of said turbine (1), a counterweight (8) is provided which, together with said turbine's (1) own weight, is dimensioned to retain said turbine (1) in said substantially vertical position at normal speed of the ocean current but to permit said turbine (1) to assume a suitable angle of inclination (φ) when subjected to temporarily increased current speeds, thereby protecting said turbine (1) from harmful flexural stresses and protecting said rotary machine (6) from being overloaded.

8. An arrangement in accordance with Claim 7, **characterized** in that said turbine (1) is fitted with a plurality of rotor units (1a -1c) arranged one below the other on said shaft (3) and displaced evenly in relation to each other around the circumference of said shaft (3), preferably three rotor units displaced 120° in relation to each other.

9. An arrangement in accordance with Claim 7 or 8, **characterized** in that a plurality of power producing units (B) formed by said buoys (2) and turbines (1) are anchored to form a group, and that cables (9) are adapted to feed electric current produced by said

units (B) to a collecting buoy (10) and from there, preferably with the help of one single cable (11), to the shore.

10. An arrangement in accordance with anyone of Claims 7-9, **characterized** in that a plurality of said turbines (1) with electric generators (6) are arranged, in a suitable configuration, in a common, large buoy or pontoon (15).

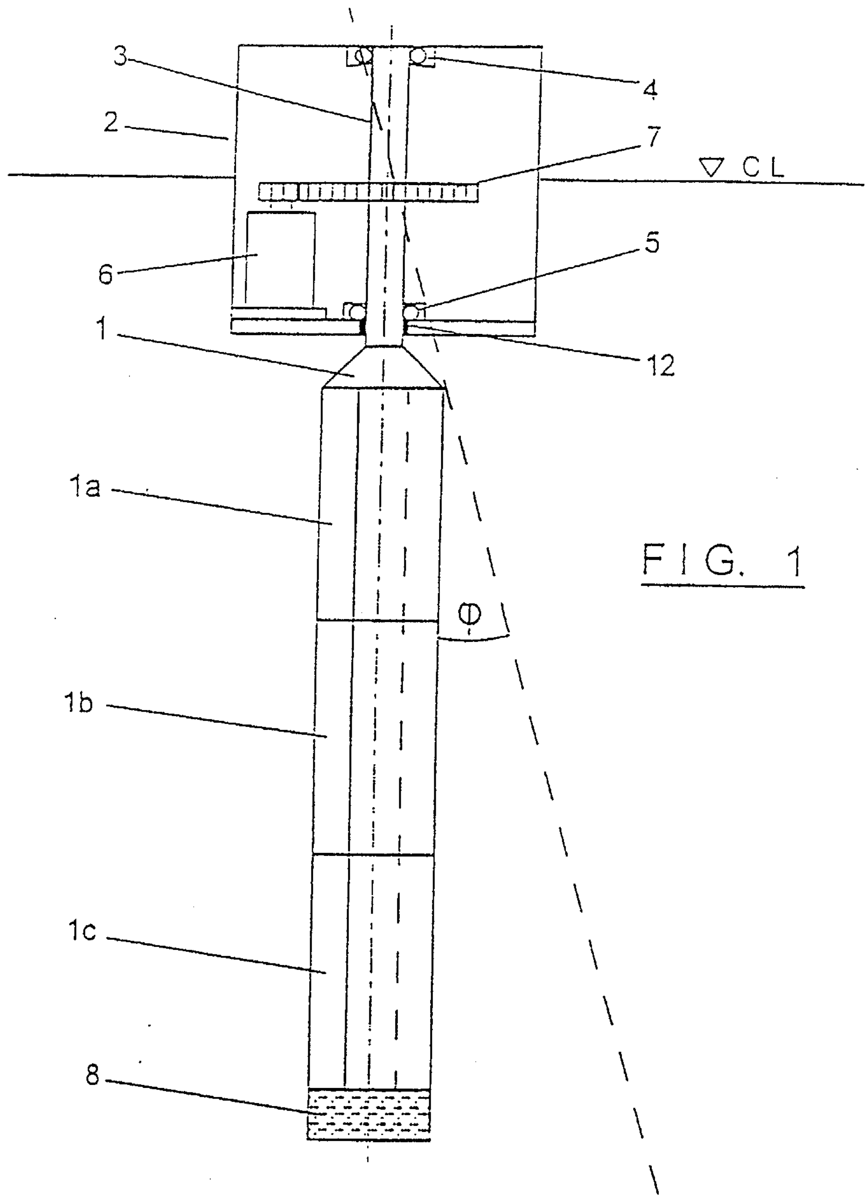


FIG. 1

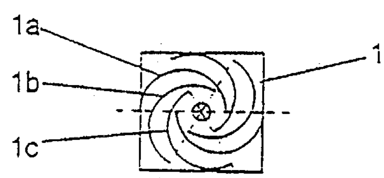


FIG. 2

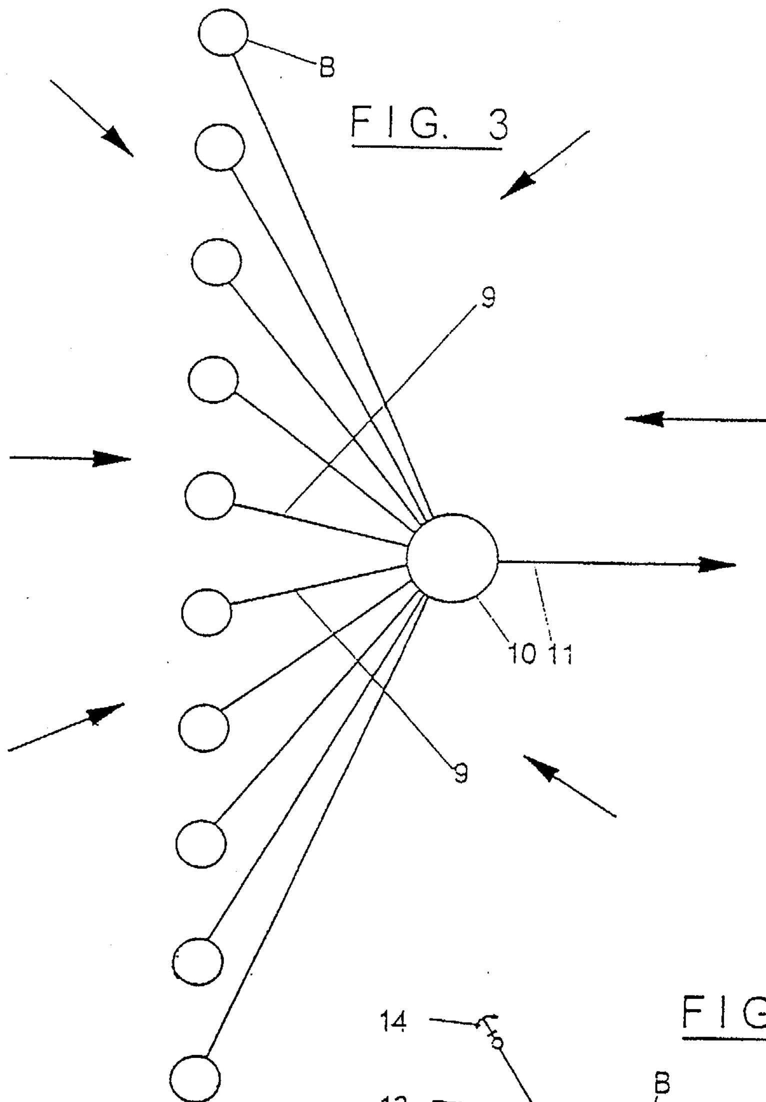


FIG. 3

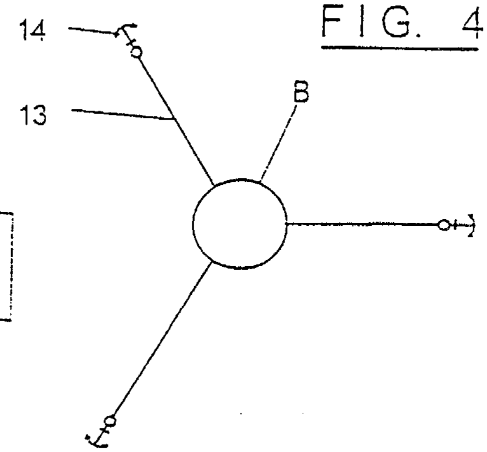


FIG. 4

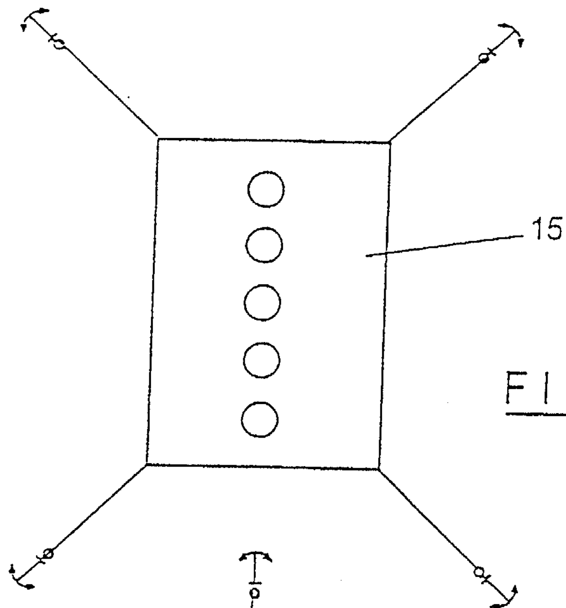


FIG. 5

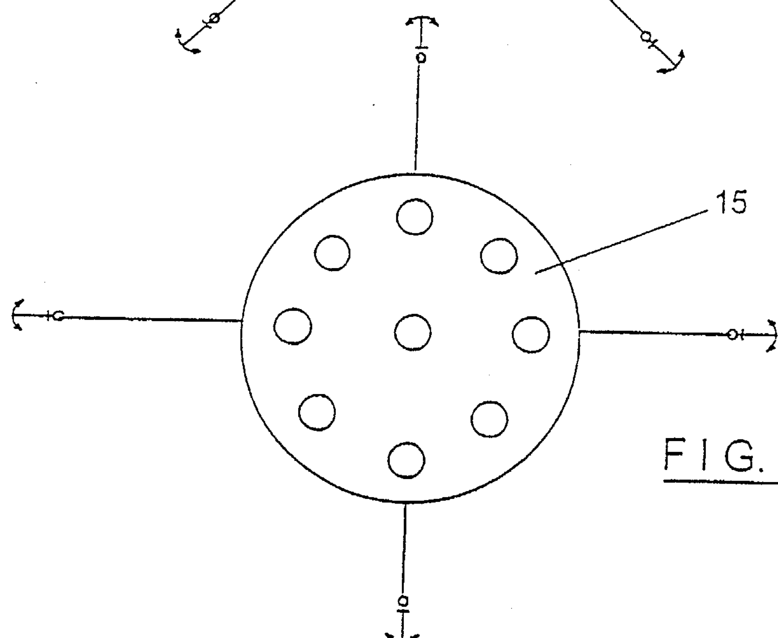


FIG. 6

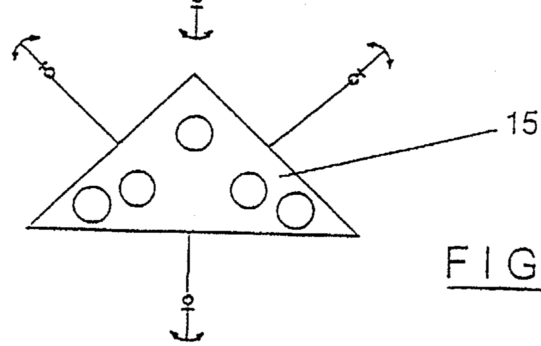


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/01640

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: F03B 13/22, F03B 7/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: F03B, F03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 604211 A (G. LOFGREN), 17 May 1998 (17.05.98), figures 1-3 --	1-10
A	GB 2119449 A (EDWARD VICTOR BYERS), 16 November 1983 (16.11.83), figures 1-3 -- --------	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
7 December 1998	09 -12- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Per-Olof Warnbo Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

03/11/98

International application No.
PCT/SE 98/01640

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 604211 A	17/05/98	NONE	
GB 2119449 A	16/11/83	NONE	

Form PCT/ISA/210 (patent family annex) (July 1992)